

### Claims

1. An optical communications device for selectively modifying a multiwavelength optical beam with a given center wavelength and edge wavelengths, while compensating for nonlinearities at the edge wavelengths which affect data reliability, comprising:

an optical modulator receiving the optical beam and introducing a selectively controllable amount of retardation in the beam; and

at least two retardation compensators in the path of the beam prior to the optical modulator, the at least two retardation compensators comprising optical wave plates providing integer multiples of retardation selected in relation to the center wavelength and edge wavelengths of the optical beam and a retardation characteristic of the optical modulator.

2. A device as set forth in claim 1 above, wherein the optical beam has a selected polarization and the at least two retardation compensators comprise at least one half wave quartz wave plate at the center wavelength and at least one nominally quarter wave plate at the center wavelength, each having selected optical axis dispositions relative to the polarization axis of the optical beam.

3. A device as set forth in claim 2 above, wherein the optical modulator comprises a voltage controlled liquid crystal cell, wherein the nominally quarter wave plate is identically equal to quarter wave at the center wavelength and the retardation compensators further comprise at least a third quartz plate of less than a tenth wave at the center wavelength to compensate for the residual cell birefringence.

4. A device as set forth in claim 3 above, wherein the device further comprises a polarizer in the optical path before the retardation compensator for assuring the direction

of the polarization of the input beam, the axis of the liquid crystal cell is at a selected angle to the input beam polarization and the optical axis of the half wave plate is at an angle of about  $15^\circ$  to the optical axis of the nominally quarter wave plate.

5. A device as set forth in claim 4 above, wherein the polarizer is a single element for transmitting an optical beam of preferred polarization.

6. A device as set forth in claim 4 above, wherein the polarizer comprises at least one polarization beam displacer.

7. A device as set forth in claim 3 above wherein the device comprises an array including a multiplicity of aligned liquid crystal cells each having independent controls and the retardation compensators are in the path of each cell, and compensate for nonlinearities at the edge wavelengths.

8. A device as set forth in claim 7 above wherein the wavelength band of interest is the C band with center wavelength of 1550 nm and edge wavelengths of 1530 nm and 1565 nm, and the device further comprises a system for diffractively separating a WDM input signal with separate wavelength signals.

9. An optical device for modifying an optical beam of known polarization and a predetermined wavelength without introducing unacceptable wavelength and temperature variations comprising:

a liquid crystal modulator receiving the incident optical beam and responsive to a control voltage, and having an established director axis, and

a beam retardation compensator disposed in the path of the beam incident on the modulator and comprising more than one low order optical wave plates

which have thickness and angles calculated to flatten liquid crystal characteristics in a wavelength band of interest.

10. A device as set forth in claim 9, wherein the compensator is a wavelength flattened, athermal compensator including a half wave plate and a nominally quarter wave plate, wherein the retardations of the wave plates are selected in accordance with the nominal center of the wavelength band of interest.

11. A device as set forth in claim 10 above, wherein the wavelength band of interest is the C band and the retardation of the half wave plate is 775 nm and the retardation of the nominally quarter wave plate is 397 to 440 nm, and wherein the optical device also includes a polarizer before the wave plates.

12. A device as set forth in claim 11 above, wherein the retardation is zero and the fast axis of the quarter wave plate and the fast axis of the liquid crystal are in antiparallel alignment.

13. A device as set forth in claim 12 above, wherein the residual wavelength dependence is limited to the material dispersion characteristics of the quartz and liquid crystal material.

14. A device as set forth in claim 13 above, wherein the extinction is maintained above 45 dB for all wavelengths from 1530 nm to 1565 nm, without linearly increasing the drive voltage for pixels corresponding to increasing wavelength, to correct for the inherent wavelength dependent birefringence of the compensator/liquid crystal combination.

15. A device as set forth in claim 14 above, wherein the device further includes a thin wave plate before the liquid crystal compensating for residual birefringence in the liquid crystal.

16. A device as set forth in claim 13 above, wherein the liquid crystal is a zero twist nematic reflective type in the electrically controlled birefringence mode.

17. An optical device for modifying a chosen characteristic of an optical beam within a wavelength band of interest, comprising:

a liquid crystal having an established director axis;

a compensator disposed in the path of the optical beam incident on the liquid crystal, the compensator comprising at least one low order quartz wave plate having an optical axis in precise alignment to each other and the director axis, and

electronic driver circuits providing a control voltage for the liquid crystal, compensating for at least one nonlinear characteristic of the device as the compensator flattens other variations.

18. The method of compensating for wavelength differences and thermal effects in modulating an optical beam with a voltage driven liquid crystal comprising the steps of:

aligning the polarity of an input signal to the director axis of the liquid crystal;

introducing a first retardation in the aligned polarized wave front;

converting the wave front from linear to elliptical polarization;

modulating the elliptically polarized beam with the liquid crystal while reflecting it back through the same elements, and

converting the elliptically polarized modified beam back to linear polarization with an introduced retardation.

19. A method as set forth in claim 18 above, including the step of introducing a fixed retardation prior to the liquid crystal.

20. The method of aligning elements in a wavelength flattened liquid crystal system having wave plates with fast and slow axes and wherein the liquid crystal cell has a predetermined director axis, comprising the steps of:

assembling successive wave plate elements using a fixed polarization optical probe beam;

detecting the amplitude of the transmission after each successive element is added;

when adding elements, measuring for an optimum extinction characteristic; and

curing the elements in fixed positions thereafter.

21. A method of reducing the temperature dependence of the high extinction state of an LC modulator assembly comprising the steps of adding a compensating half wave plate which flattens the wavelength response, minimizes the contribution of temperature dependent liquid crystal birefringence and maximizes the contribution of the temperature independent quartz wave plate birefringence to the total cell birefringence when operating in the high extinction state, such that the LC high extinction state does not require active feedback to maintain stable operation

22. A method of improving the long term stability of a liquid crystal modulator and/or switch based on a combination of quartz and liquid crystal elements, comprising the steps

of assembly of adding a compensating half wave plate to flatten the wavelength response and minimize the contribution of the less stable liquid crystal birefringence in relation to the more highly stable quartz wave plate elements birefringence in a manner such that the total cell birefringence when operating in the high extinction state is dominated by the highly stable quartz wave plate elements such that the modulator's high extinction state does not require active electronic feedback which adjusts the drive voltage to compensate for a long term drift in the liquid crystal response.

23. An LC-SLM based optical switch with improved extinction ratio based on a combination of liquid crystal, compensation and flattening elements, and including a carrier wherein at least one of the compensator and flattening wave plates are mounted to the carrier such that the attachment points are located along a single mechanical axis selected such that the thermal expansion of the wave plate along this mechanical axis is matched to the thermal expansion of the carrier to within 1 ppm/°C.